Art. XV.—*Notes on the Marine Rocks underlying Warrnambool.*

(With Two Diagrams.)

By G. S. Griffiths, F.G.S.

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The Borough Council of Warrnambool has recently bored for fresh water in the locality known as Albert Park, one and a half miles from the beach, 160 feet above sea level, and on the north east side of the town. The work was carried out under the supervision of Mr. Richard Bennett, the originator of the scheme, as I am given to understand.

The core brought up discloses an interesting series of sedimentary beds, which appear to have been laid down on a sea bottom, when this locality formed portion of an arm of the sea which extended from West to East, between the Otway Ranges and the Main Dividing Range. In early Tertiary times, Australia was elevated considerably, and the Secondary beds were greatly eroded in the area indicated. With the close of the Eocene, there was a great depression of the surface, and the Jurassic beds of the Otway were cut off from the same rocks of the flanks of the Main Dividing Range by a broad strait. Into this strait, the watercourses opening on its coast-lines brought down sand and mud, clay and chalky ooze, and these were outspread in wide thin beds. To these deposits, coral seems to have been added, for the waters, according to Professor Duncan, were warmer than those of the present seas, judging by the organic remains. These beds were subsequently raised above the sea level, and the Warrnambool bore penetrates the latest deposited, or uppermost of them, to a depth of about 400 feet. What may be the total thickness of these sediments hereabouts, cannot be stated, as there is no indication of proximity to any bottom in the bed of gault in which the boring rod broke; but in another part of this old strait, viz, at Winchelsea, a bore has

penetrated similar sediments for 2100 feet, without touching the Paleozoic bedrock.

A reference to the accompanying table of strata traversed by the Warrnambool bore, and prepared for this paper by Mr. Richard Bennett, will shew that the uppermost stratum consists of 81 feet 9 inches of limestone traversed by flint bands. This rock is of clastic origin, being composed of comminuted shell mixed with silicious sand, and bound together by a calcareous paste, and containing an abundance of flints. It is an ordinary littoral deposit. Mr. Bennett regards it as identical with the æölian limestone so abundant on the coast in the same neighbourhood, which it does resemble, both of them being accumulations of broken shell. I think, nevertheless, that the flint bands of the bore limestone differentiates the two deposits sufficiently. We know that when silicious sand is associated with calcareous sand, and the rock is below the line of saturation, the silica is rendered more or less soluble, and colloid silica segregates out of the mass just as do septaria in clays, and it thus forms flint nodules. This operation cannot proceed in a dry rock, as far as I know, and therefore flint bands in a limestone are evidence of that limestone having been immersed in water.

The æölian coast limestones of Warrnambool do not contain flints, except as remanies, as far as I can ascertain from some slight personal examination, and also from enquiry; and as they are quite recent as to age, and have never been submerged, it is unlikely that they would. The bore limestone on the other hand, was accumulated under the sea, and the flint bands attest this circumstance.

The three next beds in descending order are all clays, either red or yellow. They were deposited when this locality was more distant from the coast line, than it was when the just described and more recent calcareous sandrock above it was accumulated. The order of superposition is evidence in favor of an elevatory movement, gradually bringing the area into shallower water, so that the deep water clays become buried under shallow water sands.

Bed No. 6. Calcite, 9 ft. 5 in. Thick.

This is an uncommon formation. Nearly all limestone is composed of the comminuted remains of shells and corals bound together by calcareous paste; but this massive stratum contains no clastic materials whatever, judging from

the stone composing this part of the core, which has the appearance of having been crystallised out of a saturated solution of mineral salts. Beds of gypsum and rock-salt formed in this way are common, but massive calcite so formed is rare, as far as I can ascertain. This is probably owing to the great solubility of bicarbonate of lime. Calcite is formed in two ways :—(1) In lakes which are drying up, the carbonate of lime being supplied to it by the streams which feed it. Evaporation of its waters tends to concentrate the salts, which are then deposited in crystals on its floor. (2) In nearly closed arms of the sea, such as the Adriatic, which is fed by numerous streams, which cut their courses through calcareous or volcanic rocks. The fresh water being the lighter, spreads out as a thin sheet over the salt water, and is in this way exposed to the evaporating influences of sun and wind, whereby it becomes a concentrated solution, and so deposits its salts as crystals.

The floor of the Adriatic is now being formed of calcite, and this is the explanation given of it by the text books; but I confess that I feel a difficulty in accepting the statement, that there can be sufficient concentration of the waters in the open sea to deposit carbonate of lime.

There is another explanation offered, which is that in the presence of sodium carbonate, lime salts are decomposed, and then calcite is precipitated.

The stratum of calcite in the bore at Warrnambool may have been accumulated in one of these ways. It may represent the bottom of such a lake as those which edge the Ninety Mile Beach in Gippsland, or it might have been deposited in the sea; but it seems to me that in the latter case, that sea must have been a partly closed one like the Adriatic, rather than an open strait like Bass' Strait, in which any sufficient degree of concentration of its waters would hardly be possible. Or again like the Rhone, which has at its mouth a deposit of calcite, the Hopkins which has a course which cuts across volcanic rock and limestone beds, may have poured into this arm of the sea a large volume of water charged with bicarbonate of lime which, coming into contact with carbonate of sodium in the sea water, is reacted upon and precipitated.

Bed No. 8. Light Yellow Marl, 26 ft. 6 in. Thick.

Marl is generally a lacustrine deposit, and is then composed of the mouldered shells of mollusca, and the remains of algæ.

Marine marls generally represent old oyster banks. Either origin is possible for this stratum, as there are no organic remains to be identified in the sample from the bore.

Beds No. 12 and 16. Beds of Green Sand, full of Fossils.

These deposits are of a deeper water type than those just considered, the particles being coated with glauconite. This deposit is generally supposed to indicate a depth of from 100 to 700 fathoms; on the other hand, a species of green-sand is found opposite to the mouths of streams which traverse volcanic country, such as the Hopkins does. In this latter case, the green colour is due to a part of the pyroxene having been changed into chlorite. Such a deposit has been described by Professor Hutton as occurring at Waihao, in New Zealand.

I sent the fossiliferous sand to Dr. MacGillivray, of Sandhurst, for identification, and his report on it is, that there are no undoubted polyzoa in it, although one or two small masses in the parcel sent might be such, but none of the remains were sufficiently distinct to enable him to identify them. There were amongst the broken fossils some small calcareous tubes, which he did not understand the nature of.*

Bed No. 13. Blue Gravel, 22 ft. Thick.

No specimen of this was preserved, but from the description given, I think it may have been derived from slate rock. As no such rock outcrops, as far as I can learn, less than thirty miles away, this deposit must represent a river-borne material, and it must have reached its place of deposit at a time when the coast line was near by, as it would require a current of some swiftness to move it.

Beds 11 and 14. Blue Clays.

This material was probably derived from the same slate rocks that yielded the blue gravel, being the finer washings produced by the grinding up of the pebbles.

* Dr. Dendy, who has seen these fossils, thinks that he can identify them with those of an early Tertiary deposit found in the Isle of Wight.

Beds 15 and 17. Gault, 30 ft. Thick.

These deposits of very fine bluish calcareous clay, must probably have been laid down in comparatively deep water, as the material is so fine that it would settle very slowly; it seems to represent the rainwash of a large area covered with chalk.

Chalk beds, of Eocene age, cover large portions of the South Western corner of Victoria, and in the past they must have been much more extensively outspread. The water-courses have removed large quantities of this rock, and mingled with clay derived from the abundant lava beds, the sediment has been discharged into the sea.

Taking into consideration the nature of the various beds shown in the bore, I think that they indicate a coast line which has been repeatedly shifted throughout the Tertiary. It would be a good thing to have this bore carried down, at least until the Secondary rocks were met with, for it is a fair presumption that the Tertiaries lie immediately upon an eroded extension of the Jurassic rocks of the Otway District.

The Warrnambool Strata as Reservoirs of Artesian Waters.

The economic value of the boring operations deserves some consideration. The Warrnambool strata extend to the North in flat sheets, which rise in that direction at a rate of 35 feet in the mile, and which thin out against the Paleozoic hills at gradually increasing altitudes.

At Hexham, 30 miles distant, almost due North, the Hopkins, descending from the hills, at an altitude of 432 feet cuts its bed through Silurian rock first, then it enters the Tertiary limestones and sandstones which enwrap the older rocks, and which are the inland extensions of the rocks in the bore; and lastly it cuts into the lava which covers up the limestones.

On the North East, at Camperdown, these Tertiary beds rise to about 540 feet above sea level. They reach 731 feet at Penshurst, and 640 feet near Hamilton.

Thus the beds of the upraised Tertiary sea have a regular dip to the South. Fifty miles inland they are found at an altitude of 700 feet, whilst at Warrnambool where they have been pierced, they are 240 feet below sea level, or on a fall of over 1000 feet in that distance. The beds themselves

consist of alternate layers of porous sandstones and gravels, and impermeable clays.

The rain which falls on the land surface for a distance of 90 miles inland, is collected and conducted to the coast by these natural drains. No materials more suited to the purpose of artesian wells are known to occur. On the coast, the sea serves to dam back the fresh waters until they stand permanently a few feet above sea level at a short distance inland. Along the shore line the fresh water wells out in the sands and through rock fissures as spring water.

Near Cape Bridgewater, and a mile or so from the coast, a powerful spring wells up to the surface, and its fresh water was used largely by whalers a few years ago as a convenient source from which to fill their water tanks whilst keeping on the fishing grounds. When the boring rod entered the green-sand at 358 feet (200 feet below sea level), the water rose 225 feet in the tube, soft and fresh in quality.

It seems to me that all the conditions exist here for a good artesian water supply. As the bore goes deeper, it will tap other supplies which come from sources which are further away, and which start at greater altitudes. The hydrostatic pressure in such cases will increase, and probably will suffice to carry to the surface a large supply of good water.

The celebrated artesian well of Grenelle, near Paris, taps its water supply in just such a green-sand bed as that which lies beneath the town of Warrnambool. It would be a pity therefore, were the bore not to be sunk until the requisite water supply is obtained.

Report by Mr. R. Bennett of strata passed through in sinking a bore for artesian water at Albert Park, Warrnambool :—

No.	Strata.	Depth. ft.	in.
1.	Top soil	1	3
2.	Limestone, with flint bands	81	9
3.	Dark red clay	18	0
4.	Bright yellow clay	5	4
5.	Yellow clay and hydrous ferric oxide ...	8	9
6.	Calcite (carbonate of lime)	9	5
7.	Yellow clay, full of angular flint pebbles ...	10	3
8.	Light-yellow marl. (Sea level 161 ft. 3 in.)...	26	6

9.	Coarse Sandstone with bands of flint, full of minute shells	75	0
10.	White sand and white clay	35	0
11.	Blue clay	7	6
12.	Green sand, full of shells and coral-lines ...	14	0
13.	Blue gravel	22	0
14.	Blue clay (soft)	13	3
15.	Gault or chalky blue clay, dry and hard ...	30	0
16.	Green-sand (No. 2 bed), shells and coral-lines, out of which water rose up tubes 225 ft.	10	6
17.	Gault	29	6
	Total depth bored	398	0

Memo.—A quantity of water rose out of green sand (No. 12), but this was lost in the blue clay and gault. In No. 16, a large body of water was found, which rose up the ubes 225 feet, but on penetrating the lower bed of gault, it stopped here, the machine broke down, and I was unable to get through this bed.—R. B.